DRIVE ARRANGEMENT FOR A CONVEYING DEVICE

Field of the Invention

[0001] The present invention concerns a drive arrangement for a conveying device for the conveying of a flowing medium, in particular air or fluid, where the drive arrangement contains a drive engine whose rotational speed can be varied, an auxiliary motor that can be continuously controlled and a summing gearbox, where the summing gearbox is connected on its output side with the conveying device and on its input side with the drive engine and the auxiliary motor. Furthermore, the drive arrangement contains a control unit that controls the auxiliary motor.

Background of the Invention

[0002] Motor driven vehicles contain conveying devices that are applied for current generation and for cooling or oil supply of various vehicle components. As a rule such conveying devices, for example, generators for lighting, blowers or pumps are driven directly by the main drive engine or the internal combustion engine.

[0003] In this way oil pumps for gearboxes usually are gear pumps driven directly by the internal combustion engine or constant volume pumps that must be designed for adequate oil supply of the users at critical or unfavorable operating points, that is for operating points with low engine rotational speed, for hot oil and/or high oil consumption. In order to assure adequate lubrication and a sufficient system pressure, for example, in the case of gearboxes or in consideration of a necessary blower pressure, for example, with clutches, the operating safety in each case must be assured. Since such pumps are operated at a linear relationship to the drive engine and in practical operation higher rotational speeds are operated, this leads in large part to unnecessarily high oil supply rates, that effectively reduce the efficiency of the gearboxes.

[0004] In order to make the conveying power of conveying devices conform better to the conveying amounts actually required by the users, for pumps on the one hand, controllable pumps, such as vane pumps or radial piston pumps and on the other hand

separate pumps for lubricating oil and for pressure supply have been applied which, however, have not gained market share to date.

[0005] A similar case occurs with the drives of blower rotors that are applied to the cooling of rotor cooling water and gearboxes or hydraulic oil. By reason of the linear relationship of the amount conveyed to the rotational speed of the drive engine, such blowers must be dimensioned as relatively large components, so that a sufficiently large cooling output for each operating point is provided at the rotational speeds made available by the engine. This frequently leads to large configurations in the arrangement of the blower which in turn results in larger volumes in the configuration of the vehicle due to space problems in the positioning of the blowers in the engine compartment.

[0006] A drive arrangement has become known from US Patent No. 5,947,854 that should permit a variable control of the conveying device. Accordingly, a motor operating at constant rotational speed, particularly an electric motor, as well as an additional motor/generator that can be controlled with variable rotational speed, drive a blower rotor over a summing gearbox. By varying the rotational speed of the additional motor/generator the rotational speed of the blower can be changed. Thereby the blower's rotational speed does not exceed the rotational speed of the drive engine, even when the rotational speed of the additional motor/generator is zero. The problem here is that the arrangement of the drive components is limited to constant speed drive engines and is not appropriate to cover the rotational speed range of a Diesel engine, that, for example, is applied to land vehicles, particularly agricultural or industrial working vehicles. Rather, according to US Patent No. 5,947,854 the rotational speed of a pump or a blower can merely be reduced as compared to a constant speed drive. Furthermore, the known drive arrangement is limited in its rotational speed range of the pump or the blower due to the moderate proportion of power of the additional drive to the total user power requirement to a limited spread of rotational speeds of the pump or the blower. In this drive arrangement larger spreads of rotational speeds would lead to an unacceptable

demand for power of the additional drive and thereby a poorer total efficiency of the drive arrangement.

[0007] The task underlying the invention is seen as that of defining a drive arrangement for a conveying device of the aforementioned type, through which the above problems are overcome. In particular a drive arrangement for a conveying device is to be created that makes it possible to vary the conveying performance of the conveying device within wide limits in accordance with the demand or to adjust that performance in accordance with the demand.

Summary of the Invention

[0008] According to the invention the drive arrangement cited initially for a conveying device of a flowing medium is configured in such a way that it contains at least one sensor for the measurement of the magnitude of at least one condition of the flowing medium and the conveying performance of the conveying device can be controlled or regulated by the control arrangement as a function of at least one magnitude of the condition of the medium. This makes it possible for the control arrangement to control or regulate the auxiliary motor as a function of at least one magnitude of the condition that characterizes the demand of the amount of the flowing medium that is to be conveyed. Depending on the conveying device or the flowing medium the magnitude of the condition may be a pressure, a temperature or an amount of flow or a flow velocity, which are to be held within predetermined limits. Control signals are generated by the sensor in connection with the control unit that bring about a change in rotational speed of the auxiliary motor and make possible a variable drive of the conveying device over the summing gearbox.

[0009] According to a preferred embodiment of the invention the summing gearbox is configured as a planetary summing gearbox. This has the advantage of a simple inclusion of the auxiliary motor into the drive arrangement and leads to a compact configuration. Furthermore, this offers a number of possibilities for the connection of

the drive engine, the auxiliary motor and the conveying device.

[0010] According to a preferred embodiment of the invention the drive engine is connected with an internal gear, the auxiliary motor with a sun gear and the conveying device with a planet carrier of the planetary summing gearbox.

[0011] This arrangement assures that the auxiliary motor is required to cover only a fraction of the drive power of the conveying device but simultaneously provides a sufficiently large rotational speed adjustment range of the conveying device. The detailed adjustment of the size of the configuration of the conveying device, the adjustment range of the auxiliary motor, the gear ratio of the summing gearbox and the gear ratio between the drive engine and the internal gear permit a wide variation of the operating performance map of the drive and permit conformity with the requirements.

[0012] Other variations are also conceivable, such as the connection of the drive engine with the sun gear or the planet carrier, where the conveying device can be connected with the internal gear or the planet carrier or, respectively, with the internal gear or the sun gear and the auxiliary motor is connected with the component not yet used. The connection of the conveying device with the sun gear while connecting the auxiliary motor with the planet carrier and the drive engine with the internal gear is also conceivable.

[0013] According to a further embodiment of the invention a gear ratio step is arranged between the drive engine and the input side of the summing gearbox on the side of the drive engine, particularly its internal gear, this step is arranged for a gear ratio step-up or step-down and/or for reversal of the direction of rotation of the drive. The arrangement of a gear ratio step between the other drive components and connections or other possible connections of the planetary gearbox may also be appropriate.

[0014] The drive input gear ratio may consist of a chain of gears that contains two or more gears. This makes possible an axle spacing between the drive engine and the summing gearbox, the development of a gear ratio at the input of the summing gearbox and the development of a reversal of direction for the input rotational speed of the summing gearbox.

[0015] Furthermore, the combination with multiple step gearboxes is also possible, as well as the arrangement of a second planetary gearbox or the use of a planetary gearbox with multiple gear ratios as summing gearbox.

[0016] According to a preferred embodiment of the invention a pump or a blower is applied as conveying device where the pump is used in particular to convey lubricating or control oils or coolants such as water or the blower is used to convey air. Thereby the drive arrangement according to the invention can be used preferably for the drive of conveying devices, that are used for the cooling of drive components, the conveying of lubricating fluids or a provision of pressurizing means.

[0017] According to a further preferred embodiment of the invention at least one sensor is configured to measure magnitudes of condition of the medium that are used for the control of the drive arrangement or the auxiliary motor, it is configured as a sensor for the measurement of the pressure and/or the temperature and/or the quantity of flow and/or the velocity of flow of the flowing medium. In this way, for example, the system pressure of the hydraulic or the lubricating fluid, or the temperature of these fluids as well as the temperature of the coolant or even the quantity of flow and the flow velocity of these fluids as well as with the application of a blower as well as the temperature, the flow velocity or the quantity of flow of the air conveyed for cooling can be utilized as control magnitude.

[0018] According to a further particularly preferred embodiment of the invention an additional sensor is provided for the measurement of the rotational speed of the drive engine so that the conveying power of the conveying device can be controlled or

regulated by the control of the auxiliary motor as a function of at least one magnitude of the condition of the medium and the rotational speed of the drive engine. In this way the control of the drive arrangement or of the auxiliary motor is provided with the magnitude of the condition of the medium conveyed that is utilized as control magnitude, in addition the rotational speed of the drive engine is also sensed, so that a control dependent upon the drive engine rotational speed is also possible. The additional control of the auxiliary motor depending upon the drive engine rotational speed permits the control of extreme conditions conforming to the operation. In this way, for example, during starting of the drive engine, particularly under extreme conditions, such as in the cold, at starting rotational speeds below that of the idle rotational speed (rotational speeds below the idle rotational speed) the amount conveyed by the conveying device can be brought to zero or at least reduced by including the auxiliary motor in the control which thereby reduces the friction torque that hinders the starting process. In the range of lower drive engine rotational speeds, particularly with hot or overheated conveyed media (for example oil) however the conveyed amount produced by the conveying device can clearly be increased in order to be able to make available more lubricating oil, if necessary, on a short term basis. At higher drive engine rotational speeds, that may be required for operation under high load, the amount conveyed can clearly be reduced compared to a rigid connection of the conveying device to the drive engine rotational speed, in order to save energy. Simultaneously the amount of the conveyed medium can be increased to the maximum conveyed amount at any time in case the operating temperatures or the temperatures of the condition of the medium conveyed reach the limit values.

[0019] According to a preferred embodiment of the invention the conveying performance of the conveying device is controlled or regulated by controlling the auxiliary motor corresponding to a conveying performance map that can be provided as input as a function of the magnitude of the condition of the flowing medium, preferably the temperature, and the drive engine rotational speed. Here for every combination of these two parameters occurring in practical operation an allowable conveying performance of the conveying device and therewith a rotational speed of

the auxiliary motor is determined, for example, empirically, and entered into a conveying performance map. The conveying performance map can be stored, for example in an electronic memory, to which the control arrangement refers in generating control signals. Preferably the conveying performance map contains target value curves that are temperature dependent and can be changed in terms of the drive engine rotational speed that can be provided as input within the operating limits of the conveying device that provide as input, for example, minimum and maximum amounts conveyed, that provide as input operationally correct, or delivers the target values needed for the control unit. In this way a wide operating spectrum can be covered and the conveying device can be operated under conditions varying from a purely linear performance characteristic. The resulting advantage here is that the necessary sensors (rotational speed sensor and temperature measurement locations) are already available in modern vehicles. If, in addition the system pressure is measured, which is also usual in modern transmissions, or if falling short of the lower limits of this pressure is registered then an additional input signal can be provided for the control of the rotational speed of the auxiliary motor in such a way that when the limit value is not reached an increased amount conveyed or a maximum amount conveyed of the conveying device is sought.

[0020] According to a further embodiment of the invention the conveying performance of the conveying device is controlled or regulated by control of the auxiliary motor corresponding to a predetermined target value of the condition of the medium, preferably a target pressure of the flowing medium or a rotational speed of the drive engine depending on the target value curve of the condition of the medium, preferably a target pressure curve of the flowing medium. In that way, for example, a lubricant or an operating fluid for a gearbox must provide a certain operating pressure or system pressure that is adequate for the various operating conditions posed by the conveying device. By a target pressure provided as input to the control unit, that can be equalized determined by the sensor, the auxiliary motor can be regulated in such a way that the target pressure value provided as input for the lubricant or the operating fluid is attained. This has the advantage that the pressure control valve conventionally

contained in a gearbox control block can be completely eliminated and instead a closed control circuit can be built up in the gearbox control block so that a control can be established for the control of the auxiliary motor, with the goal of regulating the amount conveyed by the conveying device in such a way that a desired or predetermined pressure level results under all operating conditions that occur in connection with the impact pressures or flow resistance in the gearbox control system. In combination with a sensor that detects the rotational speed of the drive engine a target pressure curve can also be utilized for the regulation of the drive of the auxiliary motor. Thereby various values of the target pressure can be provided as input in a target pressure curve, for various rotational speed ranges of the drive engine, stored in an electronic memory, and supplied to the control unit for the control or regulation of the auxiliary motor. In that way, for example, for the starting process at low rotational speeds a lower target pressure can be supplied as input that rises with increasing rotational speed and reaches a maximum only at higher rotational speeds, above an idle rotational speed, where the idle rotational speed is the lower limit of the rotational speed of the drive engine in normal operation.

[0021] According to a further preferred embodiment of the invention a free wheeling device is arranged between the auxiliary motor and the summing gearbox that absorbs a torque acting upon the auxiliary motor. This arrangement is advantageous, for example, when only one direction of rotation of the auxiliary motor is utilized for the control or regulation of the conveying device and a supporting torque that must be supplied upon stopping of the auxiliary motor need not be supplied by the auxiliary motor itself. Such a free wheeling device can be provided, for example, on the drive shaft from the auxiliary motor to the sun gear, that permits the drive from the auxiliary motor to the sun gear, but supports the reverse flow of the torque from the sun gear directly on the housing.

[0022] The advantage of this drive arrangement according to the invention lies particularly in the fact that the power required for the conveying device is reduced in the rotational speed range primarily used for the drive of the drive engine

(approximately 70% to 90% of the rated rotational speed) up to 60% of the power required in today's systems needed by rigid (linear) drive arrangements. Beyond that such a drive arrangement has the advantage of varying the amount conveyed by the conveying device over the entire rotational speed range of the drive engine within wide limits in order to adjust it to the demand. In comparison to a conventional linear drive between the drive engine and the conveying device with the drive arrangement according to the invention, for example, in the low rotational speed range clearly higher conveying power levels can be called for with the same conveying device, on the other hand at high drive engine rotational speed unnecessary, excessively high conveying power demands are avoided and thereby the entire drive arrangement can be applied with optimum fuel consumption.

[0023] To acquaint persons skilled in the art most closely related to the present invention, one preferred embodiment of the invention that illustrates the best mode now contemplated for putting the invention into practice is described herein by and with reference to, the annexed drawings that form a part of the specification. The exemplary embodiment is described in detail without attempting to show all of the various forms and modifications in which the invention might be embodied. As such, the embodiment shown and described herein is illustrative, and as will become apparent to those skilled in the art, can be modified in numerous ways within the spirit and scope of the invention--the invention being measured by the appended claims and not by the details of the specification.

Brief Description of the Drawings

[0024] For a complete understanding of the objects, techniques, and structure of the invention reference should be made to the following detailed description and accompanying drawings, wherein:

[0025] Fig. 1 is a schematic configuration of a drive arrangement according to the invention with a control unit for an auxiliary motor.

[0026] Fig. 2 is a conveying performance map for a drive arrangement according to

the invention with a control of the auxiliary motor depending largely on the temperature and the drive engine rotational speed.

[0027] Fig. 3 is a target pressure curve for a drive arrangement according to the invention with a control or regulating arrangement of the auxiliary motor depending largely on pressure.

Description of the Preferred Embodiment

[0028] The drive arrangement 10 shown schematically in Figure 1 contains a drive engine for a working vehicle configured as internal combustion engine 12, an auxiliary motor configured as an electric motor 14, a summing gearbox configured as a planetary gearbox 16, as well as a conveying device configured as a pump 18, that supplies a gearbox control block 20 with pressurized oil necessary for the operation of a gearbox and that draws operating fluid from a fluid reservoir 21.

[0029] The internal combustion engine 12 of the drive arrangement 10 is coupled to a first drive shaft 26 supported in two shaft bearings 22, 24. The first drive shaft 26 is connected, fixed against rotation, to a gear 30 that is part of a gear ratio stage 28.

[0030] The electric motor 14 of the drive arrangement 10 is connected to a second drive shaft 32 that is supported in a shaft bearing 34 and is connected with a sun gear 36 of the planetary gearbox 16.

[0031] Furthermore, the planetary gearbox 16 contains an internal gear 38 as well as several planets 40 that are supported on a planet carrier 42. The planet carrier 42 is connected, fixed against rotation, to an output shaft 44. The internal gear 38 is coupled to a second gear 46 that is part of the gear ratio stage 28, it meshes directly with the first gear 30. The internal gear 38 and the second gear 46 form a unit and are supported in bearings together on the second drive shaft 32. For the further support in bearings of the planetary gearbox 16 or the second output shaft 32 further bearings 48 and 49 are used, where other known methods of bearing support could also be used,

which does not have any further importance here.

[0032] The output shaft 44 at the planet carrier 42 is rigidly connected with the pump 18, where the pump 18 conveys an operating oil fluid to the gearbox control block 20.

[0033] The gearbox control block 20 contains a temperature sensor 50 and/or a pressure sensor 52 which are connected with an electronic control unit 54 for the electric motor 14. Furthermore, a rotational speed sensor 56 is provided at the internal combustion engine 12 that is also connected with the control unit 54. The control unit 54 contains an internal control computer (not shown), that is connected with a memory (not shown), in which the performance maps, target values or target value curves necessary for the control unit are stored in memory. As a function of the values of the immediate condition, for example, operating oil temperature T_{oil}, system pressure p_{system}, and drive engine rotational speed n_{mot}, the internal control computer calculates or determines, depending on control or regulation strategy, the required control magnitudes, on the basis of which the control unit 54 generates an electrical control current I_{mot}. Generally the process operates according to two different strategies for the control or regulation of the electric motor 14 that are explained as follows on the basis of the performance map in Figure 2 and on the basis of the target value curve in Figure 3.

[0034] For a control strategy based on a rotational speed and a temperature control Figure 2 shows a conveying performance map as an example, on the basis of which the control strategy for the generation of the electrical control current I_{mot} is described. The performance map shows the conveying performance P_{flow} of the pump 18 on a vertical scale above the rotational speed of the drive engine n_{mot} on the horizontal scale. The straight lines shown in the performance map $P_{flow,max}$ and $P_{flow,min}$ characterize the maximum or the minimum conveying performance of the pump used as a function of the drive rotational speed n_{mot}. In contrast thereto the straight line $P_{flow,linear}$ characterizes the conveying performance of a corresponding pump 18 that is driven linearly or rigidly (conventionally) by the drive engine. Between the straight

lines $P_{flow,max}$ and $P_{flow,min}$ a region is characterized in which the conveying performance P_{flow} of the pump 18 can be controlled or varied by a corresponding control of the electric motor 14. As an example three control curves are shown, $P_{flow,-30°C}$, $P_{flow,40°C}$, $P_{flow,100°C}$, on the basis of which the conveying performance P_{flow} of the pump 18 can be controlled for the various oil temperatures -30°C, 40°C, and 100°C. For each desired temperature a control curve can be provided as input with which the desired conveying performance P_{flow} of the pump 18 can be controlled. For extremely cold operating conditions at about -30°C the control curve $P_{flow,-30°C}$ provides as input, for example, that the conveying performance P_{flow} of the pump 18 for drive engine rotational speeds n_{mot} is held below 400 rpm, in order to simplify the starting process in that the friction torque resulting from the operation of the pump 18 is prevented. Then the control unit 54 determines on the basis of the dominant input magnitudes n_{mot} (for example, n_{mot} = 200 rpm) and T_{oil} (T_{oil}= -30°C) the conveying performance P_{flow} (P_{flow} = 0) provided as input by the control curve for this operating point, and generates the corresponding control current $I_{mot(200,-30)}$ considering the drive engine rotational speed delivered by the rotational speed sensor 56 n_{mot} = 200 and considering geometrical inputs regarding the gear ratio. Then the control current $I_{mot(200,-30)}$ that is generated produces the rotational speed that must be developed in the electric motor and controls it, in order to hold the conveying performance P_{flow} of the pump 18 to zero. For other operating points the corresponding process is similar. In that way the conveying performance map provides as input at operating oil temperatures about -30°C and a drive engine rotational speed of 1000 rpm a conveying performance P_{flow} of the pump 18 of approximately 22.5 liters per minute. The control current $I_{mot,(1000, -30)}$ generated by the control unit 54 then generates the rotational speed to be developed by the electric motor and controls it in order to bring the conveying performance P_{flow} of the pump 18 to 22.5 liters per minute.

[0035] Furthermore, the conveying performance map reveals that in comparison to a linear (rigidly) driven pump the conveying performance can be made to conform very well to the operating requirements. In that way, particularly at low drive engine rotational speeds n_{mot} and the higher operating oil temperatures T_{oil} (T_{oil} =100°C) a

conveying performance P_{flow} of the pump lying clearly above the "linear pump conveying characteristic" $P_{flow,\ linear,}$ P_{flow} of the pump 18 can be controlled in order to better meet the performance requirements. Higher drive engine rotational speeds n_{mot} present a different problem that deviates from the "linear pump performance characteristic" $P_{flow,linear}$ in that a lower pump performance characteristic P_{flow} of the pump 18 is controlled in order to save excess conveying performance, that is, conveying performance P_{flow} above that required for the operation.

[0036] If, in addition, the system pressure is measured, which is equally possible with modern gearboxes, or if the inability to meet a target value of this pressure is registered, then from this in addition an input signal for the control of the rotational speed of the drive engine can be provided, in such a way that when the limit value is not met, fundamentally or as a function of rotational speeds and/or temperatures an increased conveyed amount or even the maximum conveyed amount of the conveying device is sought.

[0037] The control strategy based on a rotational speed and temperature control makes it possible to vary the conveying performance P_{flow} of the pump 18 across a relatively wide performance map and to meet the various operating requirements largely optimized as opposed to a conventional pump with linear drive.

[0038] Figure 3 shows a target value pressure curve depending on the drive engine rotational speed as an example on which an alternative control strategy directed at pressure measurement is based. In contrast to the control strategy based on rotational speed and temperature control, here a target value $p_{system,target}$ depending on the drive engine rotational speed is provided as input for the system pressure $p_{system,target}$ of the gearbox control block 20 that can be adjusted by control of the rotational speed of the electric motor 14 or by control of the conveying performance P_{flow} of the pump 18 for the differing drive engine rotational speeds n_{mot}. The input magnitudes for the control or regulation of the electric motor 14 in this case for each control cycle use are the drive engine rotational speed n_{mot} delivered by the rotational

speed sensor 56 as well as the actual predominant system pressure p_{system} detected by the pressure sensor 52. Corresponding to the drive engine rotational speed n_{mot} the target pressure value $p_{system,target}$ from the target value curve provided as input in the control computer associated with the drive engine rotational speed n_{mot} is determined and compared by the control computer with the system pressure p_{system}. The difference in the values of the two magnitudes ($p_{system,target,}$ and p_{system}) is used as control magnitude for the control current I_{mot} of the electric motor 14. As a function of this control magnitude the electric motor 14 is now driven faster or slower until the target pressure value $p_{system,target}$ provided as input is reached. This control cycle is repeated corresponding to control intervals provided as input so that in all operating conditions the target value provided as input by the target value curve for the target value $p_{[system,target]}$ for the system pressure p_{system} of the gearbox control block 20 is maintained.

[0039] As can be seen from the diagram in Figure 3, the target pressure $p_{system,target}$ provided as input increases for lower rotational speed values at a rate greater than proportional to the drive engine rotational speed n_{mot}, until at higher drive engine rotational speeds n_{mot} it reaches a maximum target value of 20 bar and maintains this value independently of the further rising drive engine rotational speed n_{mot}. An advantage of the control strategy oriented towards pressure measurement lies in the saving or omission of a pressure control valve and the possibility of adjusting the pressure in accord with the demand independently of magnitudes of influence, such as, for example, temperature and viscosity of the oil.

[0040] Although the invention has been described in terms of only one embodiment anyone skilled in the art will perceive many varied alternatives, modifications and variations in the light of the foregoing description as well as the drawing, all of which fall under the present invention. In that way, for example, as a supplement to the control or regulation strategy directed at pressure measurement, further target value curves could be provided as input that are utilized for pressure control as a function of the operating oil temperature T_{oil}.

[0041] Furthermore then the input value for the control unit 54 uses an operating oil temperature T_{oil} delivered by the temperature sensor 50. Then as a function of the operating oil temperature T_{oil} a cold starting assistance is then also possible for the drive engine 12 in that when a temperature limit value is not met the target pressure value is set to zero and thereby the auxiliary motor 14 is controlled in such a way that a friction torque generated by the pump 18 can be reduced or even eliminated.

[0042] In a further embodiment of the invention, that is shown as a supplement in dashed lines in Figure 1 a free wheeling device 58 is arranged between the auxiliary motor 14 and the planetary gearbox 16, which absorbs a torque applying friction to the auxiliary motor 14. This arrangement is advantageous when only one direction of rotation of the auxiliary motor 14 is utilized for the repositioning or control of the conveying arrangement 18, and a supporting torque that must be generated upon the stopping of the auxiliary motor 14 need not be generated by the auxiliary motor 14 itself. Such a free wheeling device 58 can be provided, for example, on the drive shaft 32 of the auxiliary motor 14 and the sun gear 36. Thereby a drive of the sun gear 36 by the auxiliary motor 14 is permitted, but a reverse torque flow over the sun gear is intercepted directly by the connection on the part of the housing 60 of the free wheeling device 58.

[0043] Thus it can be seen that the objects of the invention have been satisfied by the structure presented above. While in accordance with the patent statutes, only the best mode and preferred embodiment of the invention has been presented and described in detail, it is not intended to be exhaustive or to limit the invention to the precise form disclosed. Obvious modifications or variations are possible in light of the above teachings. The embodiment was chosen and described to provide the best illustration of the principles of the invention and its practical application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the

invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly and legally entitled.